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(54) GEAR SET HEALTH MONITORING SYSTEM

(57) A health monitoring system provided with an aircraft includes a temperature sensor assembly (40) and a control system (30). The temperature sensor assembly is disposed within a housing (20) and is positioned to monitor at least one of a temperature and a temperature rise of a gear of an actuator that is positioned within the housing. The control system is in communication with the temperature sensor (50). The control system is configured to output for display an indicator responsive to at least one of the temperature and the temperature rise of the gear being greater than a threshold.

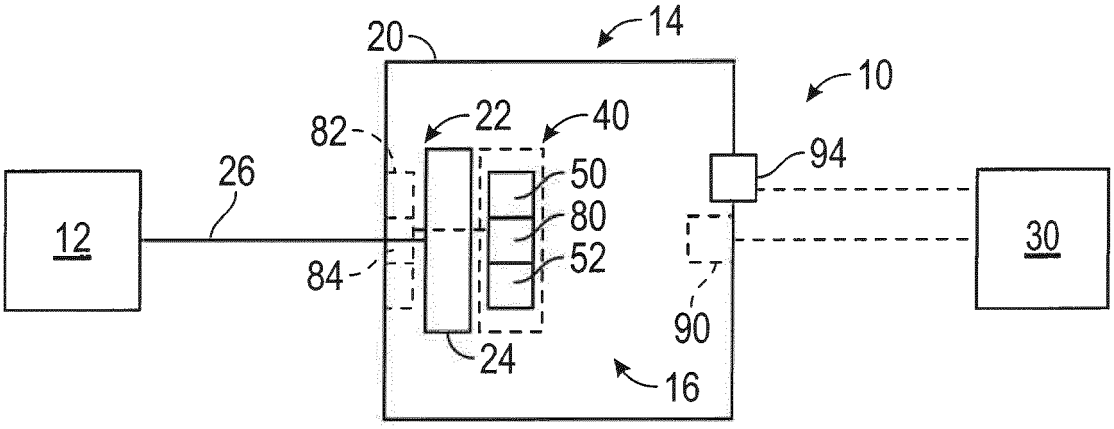

FIG. 1

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Description

BACKGROUND

[0001] Exemplary embodiments pertain to the art of prognostic health monitoring systems for gear sets.

[0002] Some machines, such as aircraft, employ drive systems that transmit or impart rotational or linear movement to a device such as a control surface. The drive systems may employ a gearbox having a gear set that may experience efficiency losses that shed energy in the form of heat. Accordingly, it is desirable to provide a prognostic health monitoring system of the gear sets to more quickly and accurately detect efficiency losses.

BRIEF DESCRIPTION

[0003] Disclosed is a drive system for an aircraft control surface. The drive system includes a gear set and a health monitoring system. The gear set is arranged to move an aircraft control surface. The health monitoring system is in communication with the gear set. The health monitoring system includes a temperature sensor and a control system. The temperature sensor is disposed on a gear of the gear set and is arranged to provide a signal indicative of at least one of a temperature and a temperature rise of the gear. The control system is arranged to receive the signal.

[0004] Also disclosed is a health monitoring system provided with an aircraft. The health monitoring system includes a temperature sensor assembly and a control system. The temperature sensor assembly is disposed within a housing and is positioned to monitor at least one of a temperature and a temperature rise of a gear of an actuator that is positioned within the housing. The control system is in communication with the temperature sensor. The control system is configured to output for display an indicator responsive to at least one of the temperature and the temperature rise of the gear being greater than a threshold.

[0005] Further disclosed is a method for monitoring health of a gear set. The method includes rotating a gear set to drive an actuator to move an aircraft control surface and receiving a signal indicative of at least one of a temperature and a temperature rise of a gear of the gear set from a temperature sensor disposed on the gear. The method further includes comparing at least one of the temperature and the temperature rise to at least one of a threshold temperature and a threshold temperature rise. Responsive to at least one of the temperature and the temperature rise being greater than at least one of the threshold temperature and the threshold temperature rise, the method outputs for display an indicator.

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] The following descriptions should not be considered limiting in any way. With reference to the accompanying drawings, like elements are numbered alike:

FIG. 1 is a system schematic of a flight control system employing a health monitoring system;

FIG. 2 is an illustrative gear set having the health monitoring system;

FIG. 3 is an illustrative gear set having the health monitoring system; and

FIG. 4 is an illustrative method of monitoring a temperature of a gear set.

DETAILED DESCRIPTION

[0007] A detailed description of one or more embodiments of the disclosed apparatus and method are presented herein by way of exemplification and not limitation with reference to the Figures.

[0008] FIG. 1 illustrates a drive system 10 for a machine. The drive system 10 may be provided within an aircraft such that the drive system 10 is a flight control system that may control or adjust a position of a movable surface such as a slat, flap, rotor, spoiler or other control surface of an aircraft. The drive system 10 may be provided with other machines having gear driven components or control surfaces. The drive system 10 includes a movable component 12, an actuator 14, and a health monitoring system 16.

[0009] The movable component 12 may be a movable surface such as an aircraft control surface or a component connected to the aircraft control surface. The movable component 12 is drivably connected to the actuator 14. The actuator 14 may be a line replaceable unit (LRU) that is arranged to provide a rotary or linear output to drive the movable component 12 or vary a position of the movable component 12.

[0010] The actuator 14 includes a housing 20 and a gear set 22 disposed within the housing 20. The housing 20 may be a gearbox or the like that rotatably receives the gear set 22. The gear set 22 includes a gear 24 that is drivably connected to the movable component 12 through an output member 26 such as a driveshaft or drive link, which extends at least partially through the housing 20.

[0011] The health monitoring system 16 is in communication with the gear set 22 and is positioned to monitor a temperature of the gear 24 of the actuator 14. The health monitoring system 16 is arranged to directly measure or monitor a temperature of the gear 24 to aid in prognostic health monitoring of the gear set 22 to detect or monitor a temperature rise of the gear set 22 that may deviate by a predetermined amount from a normal or expected temperature rise. The temperature rise may correspond to an efficiency loss of the gear set 22. A signal indicative of the temperature or temperature rise of the gear 24 or the gear set 22 is provided to or fed

back to a control system 30 that may be provided as part of the health monitoring system 16 or may be provided as part of a flight control system control unit.

[0012] The health monitoring system 16 includes a temperature sensor assembly 40. The temperature sensor assembly 40 is in wireless communication with the control system 30. The temperature sensor assembly 40 is disposed within the housing 20 and is positioned to monitor a temperature of the gear 24 of the gear set 22 and provide a signal indicative of a temperature of the gear 24 to the control system 30.

[0013] The temperature sensor assembly 40 includes a temperature sensor 50 and a transmitter 52. The temperature sensor 50 is arranged to directly measure or monitor a temperature of the gear 24 or the gear set 22. Referring to FIG. 2, the temperature sensor 50 may be disposed directly on a surface of the body of the gear 24. The temperature sensor 50 is spaced apart from gear teeth 60 of the gear 24. Referring to FIG. 3, the temperature sensor 50 may be disposed directly on a ring gear 70 or a planet carrier 72 should the gear set 22 be configured as a planetary gear set.

[0014] Referring to FIGS. 1-3, the temperature sensor 50 may be a thermocouple having the transmitter 52 or may be a thermocouple that is in communication with the transmitter 52. The transmitter 52 may provide signal processing and wireless communication between the temperature sensor 50 of the temperature sensor assembly 40 and the control system 30. The transmitter 52 and/or the temperature sensor 50 may be powered by a power source 80.

[0015] The power source 80 may be mounted directly to the gear 24, as shown in solid lines in FIG. 1. In other embodiments, the power source 80 may be mounted to the housing 20 and may be disposed about the output member 26, as shown in dashed lines in FIG. 1. The power source 80 may be a permanent magnet generator that includes a permanent magnet stator 82 and/or a permanent magnet rotor 84. The permanent magnet stator 82 may be disposed on the housing 20. The permanent magnet rotor 84 may be disposed on the output member 26 and rotatably disposed within the permanent magnet stator 82. The power source 80 may be a permanent magnet generator powered diode or may power a diode package that is disposed on the gear 24 that powers the temperature sensor 50 and/or the transmitter 52.

[0016] The transmitter 52 may wirelessly transmit the signal indicative of a temperature of the gear 24 to a receiver 90 that is provided with or associated with the control system 30. The receiver 90 may be disposed within the housing 20, disposed on the housing 20, or disposed outside the housing 20.

[0017] In at least one embodiment, the temperature sensor 50 may be a thermal camera 94 that is mounted to the housing 20 and faces towards the gear 24 of the gear set 22. The thermal camera 94 may be used in conjunction with the thermocouple that is disposed on the gear 24 to improve the accuracy of the temperature measurement of the gear 24. The thermal camera 94 extends through the housing 20 and faces towards the thermocouple. The thermal camera 94 may be disposed opposite the output member 26.

[0018] As stated previously, the control system 30 may be provided with the health monitoring system 16 or may be provided as part of the flight control system control unit. The control system 30 is in communication with the temperature sensor assembly 40 and is arranged to receive the signal indicative of the temperature of the gear 24. The control system 30 is arranged to output for display an indicator, responsive to the signal indicating the temperature of the gear 24 being greater than a threshold temperature or the temperature rise of the gear 24 being greater than a threshold temperature rise.

[0019] The control system 30 may be provided with the receiver 90 that is in communication with the transmitter 52. The receiver 90 may be powered by the power source 80 or may be separately powered.

[0020] Referring to FIG. 4, an illustrative method of monitoring the health of a gear set 22 is shown. At block 100, the gear 24 of the gear set 22 may be rotated or actuated to move the output member 26 of the actuator 14 to move the movable component 12.

[0021] At block 102, the control system 30 receives a signal indicative of a temperature of the gear 24 of the gear set 22 from the temperature sensor 50. The signal may be transmitted wirelessly to the transmitter 52 of the temperature sensor assembly 40 and received by the receiver 90 of the control system 30. The control system 30 and the temperature sensor assembly 40 may continuously monitor the temperature or temperature rise of the gear 24, may intermittently monitor the temperature or temperature rise of the gear 24, or may monitor the temperature or temperature rise of the gear 24 responsive to rotation of the gear 24 or actuation of the actuator 14.

[0022] At block 104, the control system 30 may compare the temperature or temperature rise of the gear 24 to a threshold temperature or threshold or temperature rise. Should the temperature or temperature rise of the gear 24 be less than the threshold temperature or threshold temperature rise, the method may end or may return to block 102. If the temperature or temperature rise of the gear 24 is greater than the threshold temperature or threshold temperature rise, the method may continue to block 106.

[0023] At block 106, responsive to the temperature or temperature rise of the gear 24 being greater than a threshold temperature or threshold temperature rise, the control system 30 is configured to output for display an indicator. The indicator enables an operator of the drive system 10 to the possible efficiency drop due to heat and may enable the operator to take preventative measures or schedule downtime for maintenance or replacement of line replaceable units, e.g. the actuator 14 or gear set 22.

[0024] The term "about" is intended to include the de-

gree of error associated with measurement of the particular quantity based upon the equipment available at the time of filing the application.

[0025] The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting of the present disclosure. As used herein, the singular forms "a", "an" and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms "comprises" and/or "comprising," when used in this specification, specify the presence of stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, element components, and/or groups thereof.

[0026] While the present disclosure has been described with reference to an exemplary embodiment or embodiments, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope of the invention as defined by the claims. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the present disclosure without departing from the scope of the invention. Therefore, it is intended that the present disclosure not be limited to the particular embodiment disclosed as the best mode contemplated for carrying out this present disclosure, but that the present disclosure will include all embodiments falling within the scope of the claims.

Claims

1. A drive system, comprising:

a gear set (22) arranged to move an aircraft control surface (12); and
a health monitoring system (16) in communication with the gear set, the health monitoring system, comprising:

a temperature sensor (50) disposed on a gear of the gear set and arranged to provide a signal indicative of at least one of a temperature and a temperature rise of the gear; and
a control system (30) arranged to receive the signal.

2. The drive system of claim 1, wherein the control system (30) is arranged to output for display an indicator in response to the signal indicating at least one of the temperature and the temperature rise of the gear being greater than a threshold.

3. The drive system of claim 1 or 2, wherein the temperature sensor is spaced apart from gear teeth (60) of the gear.

4. The drive system of claim 1, 2 or 3, wherein the temperature sensor is a thermocouple.

5. The drive system of any preceding claim, wherein the temperature sensor is provided with a transmitter (52).

6. The drive system of claim 5, wherein the control system is provided with a receiver (90) that is in communication with the transmitter.

7. The drive system of claim 5, further comprising a permanent magnet generator powered diode (80) arranged to power the transmitter.

8. The drive system of any preceding claim, wherein the temperature sensor is part of an assembly (40) disposed within a housing (26) and wherein the gear is positioned within the housing; and
wherein the control system (30) is in communication with the temperature sensor assembly (40), the control system being configured to output for display an indicator responsive to at least one of the temperature and the temperature rise of the gear being greater than a threshold.

9. The drive system of claim 8, wherein the temperature sensor assembly includes a thermal camera (94) that is mounted on the housing and faces towards the gear.

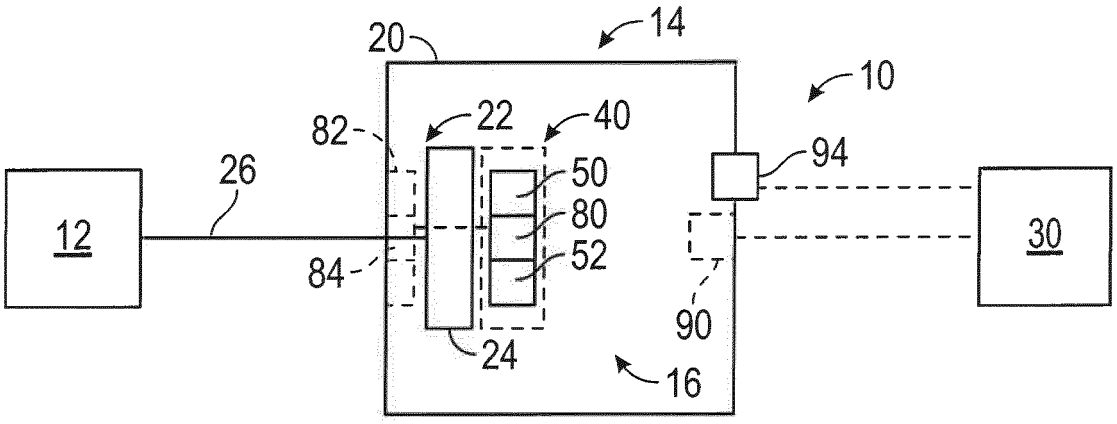
10. A method of monitoring the health of a gear set, comprising:

rotating a gear set to drive an actuator;
receiving a signal indicative of at least one of a temperature and a temperature rise of a gear of the gear set from a temperature sensor disposed on the gear; and
comparing at least one of the temperature and the temperature rise to at least one of a threshold temperature and a threshold temperature rise.

11. The method of claim 10, further comprising:

responsive to at least one of the temperature and the temperature rise being greater than at least one of the threshold temperature and the threshold temperature rise, outputting for display an indicator.

12. The method of claim 10 or 11, wherein rotating the gear set to drive the actuator moves an aircraft control surface.


20
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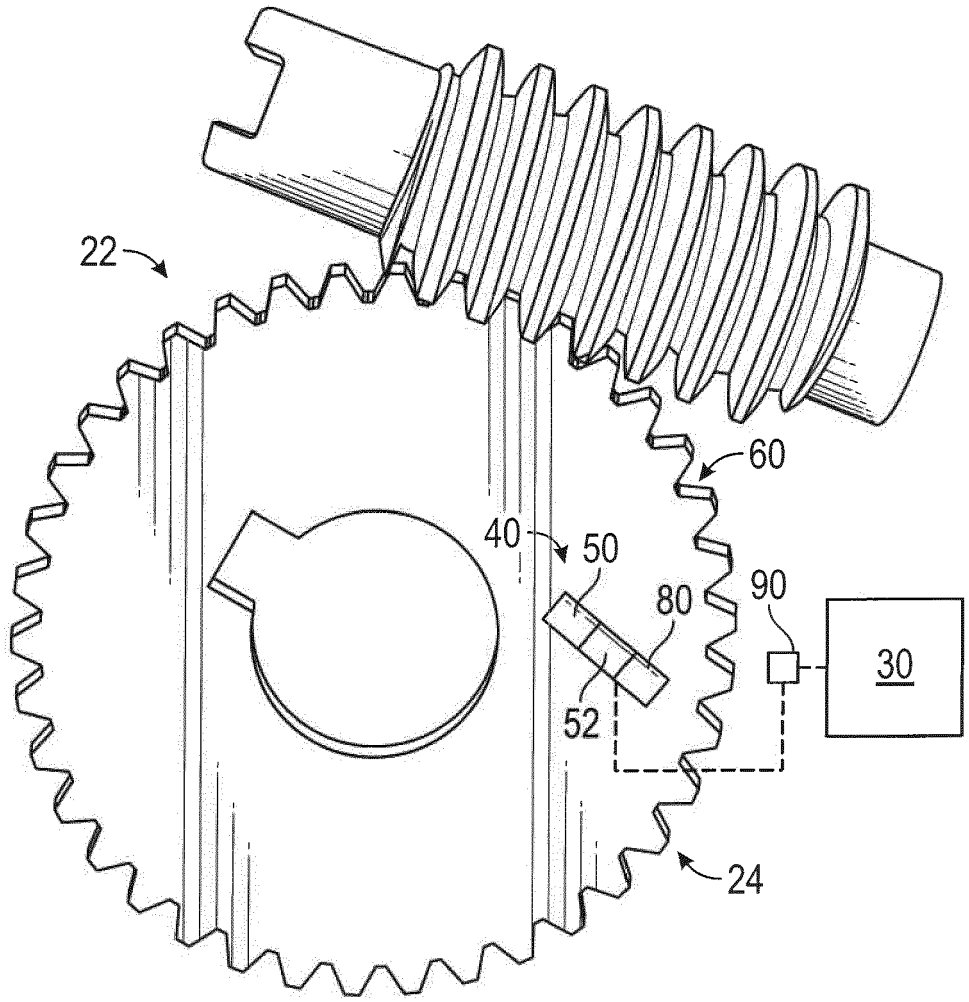
16

FIG. 1


22
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80
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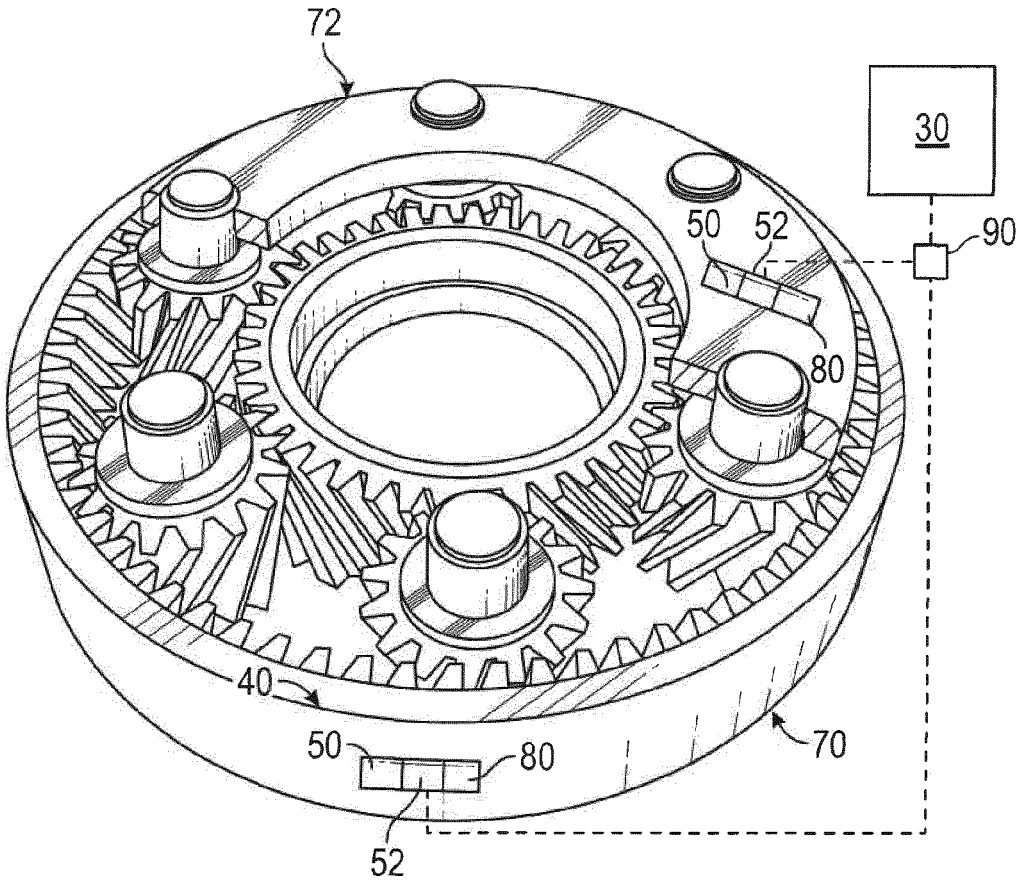
52
24

FIG. 2


72
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50
52
90
80
40
50
80
70
52

FIG. 3

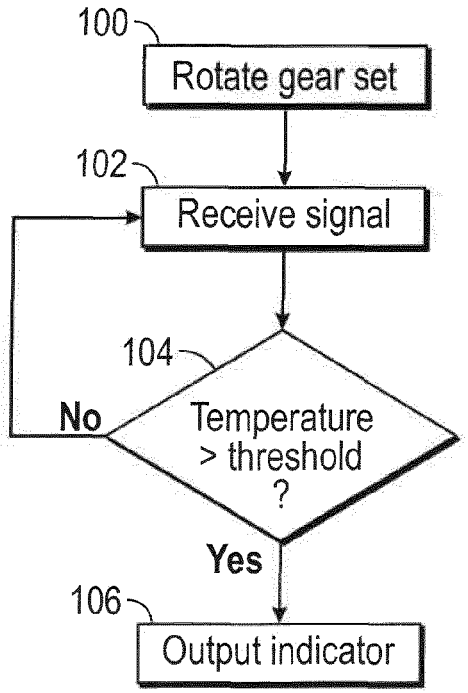
100
Rotate gear set
102
Receive signal
104
No
Temperature > threshold ?
Yes
106
Output indicator

FIG. 4

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EUROPEAN SEARCH REPORT

Application Number
EP 19 15 3960

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F16H G01N B64F G01W B64C B64D G01K

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	6 June 2019	Gubovits, János

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